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Enhancing Wheat Growth with Integrated Nutrient Management in Agroforestry Systems

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Abstract

The study was carried out during month of November to April in the year, 2021–2023 at Majhgoan Farm, Department of Silviculture and Agroforestry, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh (173 230), India with the aim of evaluating the impact of integrated nutrient management (INM) and different planting conditions on the growth and yield of wheat under *Grewia optiva*. The experiment involved eight treatments combining organic and inorganic manures under two planting conditions, replicated three times in a randomized block design (RBD) with a factorial arrangement. The results indicated that both planting conditions and nutrient sources significantly influenced wheat growth and yield. Specifically, wheat grown in open conditions (S_2), when supplemented with 50% Recommended Dose of Fertilizers (RDF) and 50% Farm Yard Manure (FYM), demonstrated superior vegetative growth and yield attributes. Among the treatments, T_5 (50% RDF+50% FYM) was identified as the most effective for improving bio–economic performance in a wheat+*Grewia optiva* agroforestry system. The study recommends adopting the T_5 nutrient management strategy in open planting conditions for cost-effective and enhanced wheat production in *Grewia optiva* Drummond–based agroforestry systems. These findings provide valuable insights for optimizing wheat cultivation in agroforestry settings, with potential benefits for the economic sustainability of farming in the region. Therefore, by adopting the agroforestry model consisting *Grewiaoptiva*+wheat, farmers can lead to good economic as well as ecological returns.

Keywords: Agroforestry system, *Grewia optiva*, growth, Nutrient management, wheat

1. Introduction

In an era marked by rapid technological advancement and growing environmental concerns, agroforestry has emerged as sustainable land utilization practice that combines agriculture and forestry resulting in a thriving and harmonious landscape. Agroforestry has demonstrated its effectiveness in land management by enhancing soil quality and conserving water resources since the beginning of agriculture (Brown et al., 2018; Montagnini and Metzel, 2017). This tremendous potential variability allows agroforestry systems to meet the environmental, economic and social needs of farmers and also reduces the risks of farmer's investments as the diversified crop range enhances the source of income (Lefroy, 2009). Agroforestry provides an opportunity for diversification of existing land–use systems, mitigating climate change and higher returns as compared to sole cropping system. Moreover, in rural areas, agroforestry improves socio-economic conditions by creating job opportunities and provides income, thereby reducing the scarcity of food production and improving the financial status (Gosling et al., 2021). Agroforestry has gained considerable attention in the scientific community which serves multiple functions and in turn, practitioners have seen these ecological benefits turn into economic benefits through the increase of agricultural output (Syahri et al., 2020). Agroforestry is not a new concept in Himachal Pradesh but it has been practiced traditionally since time immemorial. It plays a vital role in achieving sustainability in the hills farming system (Tomar et al., 2021).

Grewia optiva belonging to the Malvaceae family holds significance among various tree species cultivated in agroforestry across the Western Himalayas. Brandis (1972) noted its prevalence in the subHimalayan region, thriving up to altitudes around 1800 meters above sea level. This tree is highly valued as a primary green fodder source in the northwestern Himalayas. Where there is a shortage of green fodder during the pinch period. Agroforestry practices in the midhills of Himachal Pradesh exhibit the unique cultivation method termed Agrihorticulture, specific to the Himalayan region.

Among the various cereals, wheat is the traditional crop of Himachal Pradesh cultivated in various parts of the state. It takes up the most land area of any food crop (220.7 million hectares or 545 million acres in 2021). Wheat trade is bigger than all other crops combined. Wheat is an essential source of carbohydrates and has a global production of 771 million tonnes (850 million short tonnes) in 2021. It is the primary source of vegetable proteins in human meals worldwide, with a protein level of around 13%, which is reasonably high in comparison to other major cereals but rather poor in protein quality (supplying key amino acids) (Safdaret al., 2023) In India, it is widely intercropped with *Populus deltoides*, *Grewia optiva*, *Eucalyptus tereticornis* in Uttarakhand, Punjab, Haryana, U.P., H.P., and Bihar states as well as parts of M.P, Chhattisgarh, and W.B also (Newaj et al., 2018).

Apart from this, application of FYM enhances soil structure, increases water retention capacity, promotes soil microbial activity and augments the availability of nutrients for plants as in accordance with Ayyub et al. (2011). Farmyard manure (FYM) has been acknowledged for its ability to sustain soil productivity over prolonged periods compared to synthetic fertilizers (Anonymous, 1975). Vermicompost aids in revitalizing microbial populations, supplying essential nutrients, enhancing soil texture and improving water retention capacity. Moreover, it positively impacts soil pH and stimulates soil enzyme activities (Maheswarippa et al., 1999). The involvement of earthworms in vermicomposting proves advantageous for enhancing soil physical conditions and fostering plant growth.

2. Materials and Methods

The present study was conducted during the month of November in both the years i.e. 2022 and 2023 in ten year old *Grewia optiva* orchard established at Experimental farm at Majhgoan of Department of Silviculture and Agroforestry, Dr. YS Parmar University of Horticulture and Forestry, Nauni–Solan Himachal Pradesh and harvested in the month of April in both the year. The site is located at 30°51’06.42”N latitude, 77°09’48.57”E longitude and 1200 m elevation above the mean sea level (Figure 1 and 2). For the application of different doses of organic and inorganic manures viz., T_1: RDF (Recommended dose of Fertilizer), T_2: FYM (100% N equivalent basis), T_3: Vermicompost (100% N equivalent basis), T_4: Goat manure (100% N equivalent basis), T_5: 50% RDF+50% FYM, T_6: 50% RDF+50% VC, T_7: 50% RDF+50% GM, T_8: Control were applied to different plots randomly. Two planting conditions (S_1: under *Grewia optiva* Drummond. based agroforestry system and S_2: open conditions) with three replications were assessed in the RBD (factorial) design and analyzed by R software.

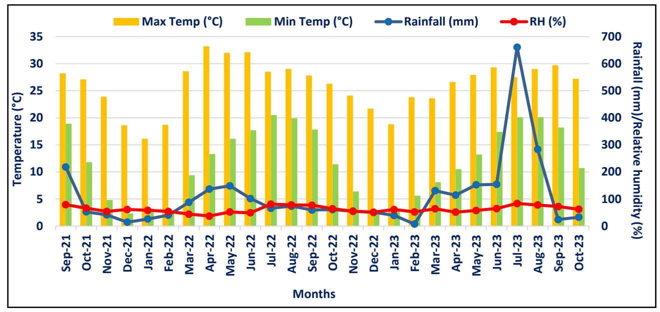

Figure 1: Meteorological data of the study site for the year 2021, 2022 and 2023

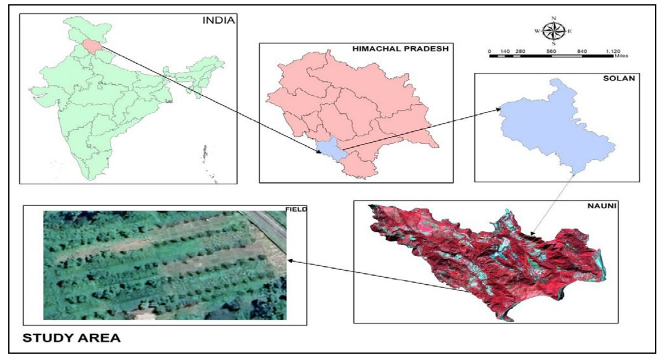

Figure 2: Study area map

3. Observation Recorded

The plant growth parameters like plant height, number of tillers plant^{-1}, spike length, grain yield, straw yield and biological yield were measured at harvest. Five randomly selected plants from each treatment for all three replications were selected and analysed. The mean of all five plants gave average values for all the parameters for each replication. An economic analysis was conducted on a per hectare basis of both the cropping systems. The cost of cultivation of wheat under agroforestry system and as sole cropping system was worked out on the per hectare basis. The gross returns (₹ ha^{-1}) were worked out by multiplying the quantity of the seed (q ha^{-1}) by the present market price (₹ q^{-1}) of the seed. Net returns were worked out by deducting cost of cultivation from the gross returns. BCR was calculated by dividing Gross returns from the Cost of cultivation.

4. Results and Discussion

4.1. Growth parameters of wheat

The average data from both years indicated that the maximum (81.32 cm) plant heightwas recorded in the S_2 (open condition), whereas the minimum height of (76.20 cm) was recorded in the S_1 (under *Grewia optiva* based agroforestry systems). Within the various treatments involving organic and inorganic fertilizers, the tallest (85.45 cm) plantheight was observed in treatment T_5 (50% RDF+50% FYM), while the shortest (68.65 cm), was found in T_8 (control). The combined influence of treatment and planting conditions (T×S) did not demonstrate a substantial effect on plant height.

In case of number of tillers per plant, the pooled data revealed that among planting conditions, the maximum number of tillers plant^{-1} (6.71) was recorded in S_2 (open condition), while the lowest (6.13) occurred in S_1 (under *Grewia optiva* based agroforestry systems). Regarding various doses of Integrated Nutrient Management (INM), the maximum (6.83) number of tillers per plant was observed in T_5 (50% RDF+50% FYM), statistically comparable to T_6 50% RDF+50% VC (6.72), T_7 50% RDF+50% (6.60), T_1 RDF (Recommended dose of Fertilizer) 6.53, and T_2 (100% FYM) 6.42 whereas the minimum (5.70) was recorded in T_8 (control). Similarly, the spike length was significant effected by the planting condition maximum spike length (6.83 cm) was recorded under S_2 (open condition), whereas minimum spike length (6.31 cm) was recorded under S_1 (under *Grewia optiva* based agroforestry systems). Among fertilizer treatments, maximum spike length (7.02 cm) wasobserved in T_5 (50% RDF+50% FYM), which was statistically at par with T_6 and T_7. Whereas minimum spike length (5.92 cm) was observed in T_8 (control).

The results of the wheat growth parameters showed in Table 1 revealed a significant effect of *Grewia optiva* on all the growth parameters viz. plant height, number of tillers per plant, number of spike per spikelets and spike length of wheat. Inimical effect of trees on the wheat crop was evident as vicinity to the tree rows led to a notable decrease in all four growth parameters that were investigated. These findings may be attributed to lower availability of PAR due to tree canopy and higher contention for water and nutrients, posed by tree roots. It may also be due to the fact that under higher aged plantation, availability of photosynthetic active radiations for intercrops beneath the tree canopy decreases drastically resulting in poor growth of understory crops (Virk et al., 2017). Sharma et al. (2000) observed similar results of reduction in plant population of wheat crop by 34.2% due to low light availability under Poplar tree canopy as compared to open conditions; the control (open) field had higher crop height compared to plants under shade. These results are also coherent with Sirohi et al. (2023) who reported lower wheat growth under Poplar based agroforestry systems, vis-à-vis open cropping system.

Similarly, manure and fertilizer application also exhibited a significant effect on the growth attributes of wheat. Highest value of growth parameters were observed in T_5 (50% RDF+50% FYM on a nitrogen equivalence basis). This effect can be assigned to potentially instant as well as stabilized nutrient supply over a period of time, catering to the early stage as well as extended nutrient requirements of the crop by 50% RDF and 50% FYM, respectively. These results are in consonance with the findings of Khan et al. (2023), Bhatt et al. (2021) and Qiao et al. (2020) who all have observed similar results with integrated nutrients management. The increase in yield with integrated application of nitrogen and farm manure may be due to high level of microbial activity which improved organic matter decomposition required for plant growth (Ibrahim et al., 2008), Bonde et al. (2009) and Kumar et al. (2010).

Table 1: Effect of planting conditions and integrated nutrient management (INM) on the growth parameters of wheat (*Triticum aestivum*) under *Grewia optiva* Drummond. based agroforestry system

Systems (S) Treatments (T)	Plant height (cm)			No. of tillers plant^{-1}			Spike length (cm)		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1	78.80^{de}	83.10^{bc}	80.95^{c}	6.13^{defg}	6.92^{abc}	6.53^{ab}	6.41^{cdef}	6.82^{bc}	6.61^{bcd}
T_2	74.85^{f}	80.10^{de}	77.47^{d}	6.10^{defg}	6.73^{abcd}	6.42^{ab}	6.37^{def}	6.68^{cd}	6.52^{cd}
T_3	73.37^{fg}	79.32^{de}	76.34^{de}	6.05^{efg}	6.56^{abcde}	6.30^{b}	6.29^{def}	6.46^{cdef}	6.37^{d}
T_4	72.07^{fg}	78.42^{e}	75.25^{e}	6.04^{efg}	6.48^{bcdef}	6.26^{b}	6.18^{ef}	6.59^{cde}	6.38^{d}
T_5	83.52^{bc}	87.37^{a}	85.45^{a}	6.51^{abcdef}	7.16^{a}	6.83^{a}	6.61^{cde}	7.43^{a}	7.02^{a}
T_6	81.21^{cd}	85.82^{ab}	83.51^{ab}	6.39^{bcdef}	7.04^{ab}	6.72^{ab}	6.54^{cdef}	7.24^{a}	6.89^{ab}
T_7	79.79^{de}	85.11^{ab}	82.45^{bc}	6.26^{cdef}	6.95^{ab}	6.60^{ab}	6.39^{cdef}	7.27^{ab}	6.83^{abc}
T_8	66.00^{h}	71.30^{g}	68.65^{f}	5.52^{g}	5.88^{fg}	5.70^{c}	5.71^{g}	6.12^{fg}	5.92^{e}
Mean	76.20^{b}	81.32^{a}		6.13^{b}	6.71^{a}		6.31^{b}	6.83^{a}	
CD (p=0.05)	S	0.98		S	0.23		S	0.15	
	T	1.96		T	0.46		T	0.31	
	S×T	NS		S×T	NS		S×T	NS	

*Mean values of each growth and yield parameters followed by the same letter are not significantly different at p=0.05, T: Treatments, S: Planting conditions, Y: Years, T_1: RDF (Recommended dose of Fertilizer), T_2: FYM (100% N equivalent basis), T_3: Vermicompost (100% N equivalent basis), T_4: Goat manure (100% N equivalent basis), T_5: 50% RDF+50% FYM, T_6: 50% RDF+50% VC, T_7: 50% RDF+50% GM, T_8: Control, S_1: under *Grewia optiva* based agroforestry system and S_2: Open conditions

4.2. Yield parameters of wheat

The pooled data of both the year reveals that both planting conditions and organic and inorganic fertilizers had registered a significant effect on the grain yield (q ha^{-1}). Among planting conditions maximum (31.78 q ha^{-1}) grain yield was recorded in S_2 (open condition) and minimum (26.78 q ha^{-1}) was recorded in S_1 (under *Grewia optiva* based agroforestry systems). Different doses of fertilizers showed a significant effect on the grain yield (q ha^{-1}); maximum (34.03 q ha^{-1}) grain yield was recorded in T_5 (50% RDF+50% FYM) and minimum (21.77 q ha^{-1}) grain yield was recorded in T_8 (control).

Considering straw yield, both planting conditions, organic and inorganic fertilizers had registered a significant effect. Among planting conditions maximum (53.43 q ha^{-1}) straw yield was recorded in S_2 (open condition) and minimum (50.80 q ha^{-1}) was recorded in S_1 (under *Grewia optiva* based agroforestry systems). Different doses of organic and inorganic fertilizers show a significant effect on the straw yield; maximum (57.13 q ha^{-1}) straw yield was recorded in T_5 (50% RDF+50% FYM) which was statistically at par with the T_6 and minimum (45.86 q ha^{-1}) straw yield was recorded in T_8 (control).

The biological yield also significantly affected by both planting conditions and integrated nutrient management. Among planting conditions maximum (85.21 q ha^{-1}) biological yield was recorded in S_2 (open condition) and minimum (77.58 q ha^{-1}) was recorded in S_1 (under *Grewia optiva* based agroforestry systems). Different doses of organic and inorganic fertilizers show a significant effect on the biological yield; maximum (91.16 q ha^{-1}) biological yield was recorded in T_5 (50% RDF+50% FYM) which was statically at par with T_6 and minimum (67.63 q ha^{-1}) biological yield was recorded in T_8 (control).

The perusal of the data presented in Table 2 revealed a remarkable effect on the yield parameters viz. grain yield, straw yield and biological yield of wheat under *Grewia optiva* canopy. All yield parameters were found elevated under the open condition and diminished under the tree canopy. Reduced yield under the trees is comprehensible as growth attributes were also restricted under trees. The competition with tree roots for water and nutrients as well as reduced sunlight at ground level under tree reduced the growth of plants and consequently the yield.

The reduced yield of grain in wheat under agroforestry relative to sole wheat demonstrate the existence of competition was also reported by Sarvade et al. (2014) Likewise Bist et al. (2017) had also observed decline in biological yield of wheat under poplar tree.Similarly, Gill et al. (2009) also confirmed the decline in the biological yield under *Meliadubia* tree as compared to sole cropping.

On the other hand the integrated nutrient management had also showed significant effect on the yield attributes of wheat. Among various nutrient applications, T_5 (50% recommended dose+50% farmyard manure by nitrogen equivalence) proved

Table 2: Effect of planting conditions and integrated nutrient management (INM) on the yield parameters of wheat (*Triticum aestivum*) under *Grewia optiva* Drummond. based agroforestry system

Systems (S) Treatments (T)	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})			Biological yield (q ha^{-1})		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1	27.27^{fgh}	33.10^{bc}	30.18^{bcd}	51.34^{bcde}	55.11^{ab}	53.22^{bc}	78.61^{fgh}	88.21^{bc}	83.41^{bc}
T_2	26.26^{ghi}	32.27^{bcd}	29.26^{cde}	49.98^{cde}	52.72^{bcd}	51.35^{bc}	76.23^{ghi}	84.99^{bcde}	80.61^{cd}
T_3	25.13^{hi}	30.29^{cde}	27.71^{e}	50.04^{cde}	52.27^{bcd}	51.16^{c}	75.17^{hi}	82.57^{cdef}	78.87^{d}
T_4	25.68^{ghi}	30.51^{cde}	28.10^{de}	49.23^{def}	51.13^{bcde}	50.18^{c}	74.91^{hi}	81.64^{defg}	78.27^{d}
T_5	31.51^{bcde}	36.55^{a}	34.03^{a}	55.45^{ab}	58.80^{a}	57.13^{a}	86.96^{bcd}	95.35^{a}	91.16^{a}
T_6	29.62^{def}	34.40^{ab}	32.01^{ab}	53.64^{bcd}	56.05^{ab}	54.85^{ab}	83.26^{cdef}	90.45^{ab}	86.85^{ab}
T_7	28.61^{efg}	33.78^{ab}	31.19^{bc}	51.78^{bcde}	54.54^{abc}	53.16^{bc}	80.39^{efgh}	88.31^{bc}	84.35^{bc}
T_8	20.16^{j}	23.38^{i}	21.77^{f}	44.91^{f}	46.81^{ef}	45.86^{d}	65.07^{j}	70.19^{ij}	67.63^{e}
Mean	26.78^{b}	31.78^{a}		50.80^{b}	53.43^{a}		77.58^{b}	85.21^{a}	
CD (p=0.05)	S	1.04		S	1.79		S	2.16	
	T	NS		T	3.58		T	4.33	
	S×T	NS		S×T	NS		S×T	NS	

*Mean values of each growth and yield parameters followed by the same letter are not significantly different at p=0.05, T: Treatments, S: Planting conditions, Y: Years, T_1: RDF (Recommended dose of Fertilizer), T_2: FYM (100% N equivalent basis), T_3: Vermicompost (100% N equivalent basis), T_4: Goat manure (100% N equivalent basis), T_5: 50% RDF+50% FYM, T_6: 50% RDF+50% VC, T_7: 50% RDF+50% GM, T_8: Control, S_1: under *Grewia optiva* based agroforestry system and S_2: Open conditions to be the best nutrient treatment for all the yield parameters of wheat the best results in the combined application of organic and inorganic manure as compared to control may be due the immediate supply of the nutrients from the RDF along with sustain supply of nutrient through FYM for the growing season. The present outcomes were also supported by the Kaur and Singh (2022) and Bhat et al. (2021) who all reported the maximum yield of crops under combined application of organic and inorganic manures. Similar results were also reported by Bijalwan et al. (2014), Kumar et al. (2010), Bonde et al. (2009) and Meng et al. (2005)

4.3. Bio economics of the system

The cost of cultivation pertaining to the planting conditions showed that S_1 (wheat under *Grewia optiva* agroforestry) marked the highest (₹ 90987.01 ha^{-1}) cost of cultivation while, S_2 (wheat in open conditions) registered the minimum (₹ 70294.15 ha^{-1}) cost of cultivation. Similarly, under different fertilizer treatment, T_3 (100% vermicompost) resulted in a higher (₹ 119196.60 ha^{-1}) cost of cultivation whereas; T_8 control (no manure) yielded the lowest (₹ 45667.64 ha^{-1}) cost of cultivation.

Data pertaining to gross returns showed that S_1 (wheat+ *Grewia optiva* agroforestry) marked the highest gross return (₹ 130123.29 ha^{-1}) while, S_2 (wheat in open conditions) registered the minimum (₹ 92201.90 ha^{-1}). Likewise, among different fertilizer treatments, T_5 (50% RDF+50% FYM) yielded a higher gross return (₹ 137780.7 ha^{-1}), whereas T_8 control (no manure) resulted in the lowest (₹ 54479.90 ha^{-1}) gross return. The net returns was also marked highest (₹ 39136.28 ha^{-1}) under S_1 (wheat under *Grewia optiva* agroforestry) while S_2 (wheat in open conditions) recorded the minimum (₹ 55 21907.74 ha^{-1}) net returns. Similarly, under different nutrient treatments, T_5 (50% RDF+50% FYM) resulted in a higher (₹ 59015.23 ha^{-1}) net returns, whereas, T_3 (100% vermicompost) results the lowest (₹ 8811.43 ha^{-1}) net returns.

The benefit cost ratio of both the system revealed that S_2 (wheat under *Grewia optiva* agroforestry) had the highest benefit:cost ratio (1.45) whereas, S_1 (wheat in open conditions) registered the lowest (1.32). Similarly, among various fertilizer treatments T_5 (50% RDF+50% FYM) recorded maximum benefit-cost ratio (1.74), while T_3 100% vermicompost resulted in the minimum (1.16) benefit-cost ratio. These findings are

Table 3: Effect of planting conditions and integrated nutrient management (INM) on the bio economics of wheat (*Triticum aestivum*) under *Grewia optiva* Drummond. based agroforestry system

Systems (S) Treatments (T)	Cost of cultivation (₹ ha^{-1})			Gross return (₹ ha^{-1})		
	S_1	S_2	Mean	S_1	S_2	Mean
T_1	81658.32	47483.69	64571.01	120147.98	63258.96	91703.47
T_2	116047.30	97145.86	106596.6	140685.90	112697.54	126691.7
T_3	127647.30	110745.81	119196.6	144258.32	130684.65	137471.5
T_4	91647.30	70745.81	81196.56	133641.71	94164.90	113903.3
T_5	89216.18	68314.69	78765.44	159687.21	115874.12	137780.7
T_6	95016.18	74114.69	84565.44	148629.71	94672.50	121651.1
T_7	75016.18	54114.69	64565.44	127956.85	83283.00	105619.9
T_8	51647.30	39687.98	45667.64	65978.65	42979.50	54479.08
Mean	90987.01	70294.15		130123.29	92201.90	

Table 3: Continue...

	Net return (₹ ha^{-1})			B:C Ratio		
	S_1	S_2	Mean	S_1	S_2	Mean
T_1	38489.66	15775.27	27132.47	1.47	1.33	1.40
T_2	24638.60	15551.68	20095.14	1.21	1.16	1.19
T_3	16611.02	19938.84	18274.93	1.13	1.18	1.16
T_4	41994.41	23419.09	32706.75	1.46	1.33	1.39
T_5	70471.03	47559.43	59015.23	1.79	1.70	1.74
T_6	53613.53	20557.81	37085.67	1.56	1.28	1.42
T_7	52940.67	29168.31	41054.49	1.71	1.54	1.62
T_8	14331.35	3291.52	8811.43	1.28	1.08	1.18
Mean	39136.28	21907.74		1.45	1.32	

consistent with the research of Kombra et al. (2023), who observed that eucalyptus+wheat based agroforestry system yielded the highest net return (₹ 99265.67 ha^{-1}) compared to the control under wheat. Bhatia et al. (2023) reported a higher benefit-cost ratio (2.26) under the agroforestry system (soybean+Harar) compared to sole soybean (Table 3).

5. Conclusion

The study indicates that wheat can be successfully cultivated beneath *Grewia optiva* by combining organic and inorganic fertilizers. While the wheat yield was somewhat lower under tree canopy, tree provides significant direct benefits, which have a high market value and can substantially boost income. Based on the experiment, it is recommended that farmers in the mid–hill Himalayan region adopt 50% RDF and 50% FYM for economic improvement. However, further experiments are necessary for more precise validation.

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